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Perceptual Processing Capabilities Relevant to Design of Visual Displays for Information Management in Advanced Airborne Weapon Systems

Tommy R. Morrison, Ph.D.
Naval Aerospace Medical Research Laboratory
Naval Air Station, Pensacola, Florida 32508-5700

SUMMARY

A review of P-3C TACCO task analytic data provided the basis for developing an experimental paradigm for investigating cognitive processing demands characteristic of Naval aviation displays. Stepwise regression analyses of the obtained data provided assessment of processing times associated with the various display demands and regression equations for predicting performance. The results provide human performance data relevant to human factors and design engineers involved in developing visual displays to enhance information management in advanced airborne weapon systems.

INTRODUCTION

The development of systems that provide the capability to manage information in a manner which enhances effective, timely decision-making is critical to practically all military aviation systems. Increased threats and corresponding sensor technology improvements; advances in computers, software, and display capabilities; and advances in control/input devices continue to increase information management requirements.

In many military systems, a critical aspect of information management continues to be the interface between information and the human element in the system. The following quote vividly describes the information display overload problem in the context of battle managment systems: '"The most demanding and immediate problem in battle management is the inundation of the decision-maker with information from multiple sensors that are growing in capability, accuracy, and speed," says Rome Air Development Center's Colonel O'Berry. "He can find himself up to the eyebrows in bits and bytes in a matter of seconds in a crisis situation."' (1, p. 60).

Reising and Emerson (2) predict certain characteristics for the cockpit of the year 2000 that include unprecedented information processing capabilities. The high degree of information saturation is evident from the cockpit's various information management subsystems: CRTs (plus possible use of flat-panel displays), voice controls, touch sensitive overlays, programmable switches, helmet-mounted sights/displays, color pictorial formats, and artificial intelligence (in the form of an electronic crewmember). These integrated controls and displays will provide multiple ways to access information and perform the same system function, and multiple displays by which the same information can be displayed different ways, in different locations.

With increased data management requirements, more tasks may become automated. Various levels of automation are possible, which range from systems that suggest decision alternatives to systems that make and implement decisions, informing the operator afterwards (3). In such system control situations, a critical aspect relevant to mission success is the manner in which information is conveyed to the operator. The time required for the operator to interpret and act upon the information from the automated system component becomes a critical element in the system's performance capabilities. In order for the human to mentally keep up with automated system processes, the human's perceptual-cognitive capabilities relevant to the particular system demands must be sufficiently assessed. Thus, for highly automated systems to be safe, efficient, and reliable, information displayed to the operator about system states and the operator's perceptual capabilities must be compatible--even in automated systems.

The investigation was part of an ongoing program at the Naval Aerospace Medical Research Laboratory (NAMRL) designed to address some shortcomings in system performance attributed to the failure to adequately take into account human capabilities in the design of complex weapons systems (4, 5). The goal of the current program is to provide mean-ingful, performance-based assessment of operator cognitive capabilities and limitations across broad categories of aviation-relevant tasking and workload requirements. Specific objectives of this study include: (1) the development of a tasking and measurement system for assessing cognitive demands in a visual display task requiring demands similar to those in real naval aviation tasks; and (2) the development of a process-based model of cognitive capabilities useful for predicting performance to complex visual displays. The visual display task employed in the present investigation resulted from a review of visual information processing demands imposed upon the P-3C Tactical Coordinator (TACCO) as described by Doll (6). The findings from the present investigation should provide useful information relevant to the design of the visual interface in information systems.

METHOD

Subjects. A total of 116 Naval and Marine Officers entering the Navy flight program at Pensacola, Florida, participated in this study. All had 20/20 or better central visual acuity and were screened for color vision with the Farnsworth Lantern. The 116 subjects were divided into two groups. Group 1 consisted of 14 Naval and 37 Marine officers; all were male, and their ages ranged from 22 to 30 years, with a mean age of 23 years. Group 2 consisted of 62 Naval and 3 Marine officers; one was female; and their ages ranged from 22 to 30 years, with a mean age of 25 years.

Apparatus. The test station consisted of a test booth enclosure in which the seated subject performed the experimental task. A television monitor and Caramate rear-projection slide system were positioned in front of the subject, with the monitor left of center and the projector right of center. A response keypad was positioned directly in front of the subject. The keypad contained keys labeled 0-9, True, False, and Enter. An Apple microcomputer, interfaced to a switching system, controlled task presentation and recorded subject response times.

One hundred and twenty slides were presented on the display screen. The illuminated display screen area was 15.25 cm x 15.25 cm and was divided into quadrants by horizontal and vertical lines (each had 1 mm stroke width). A 7.62-cm diameter circle (stroke width = 1 mm) was centered in the display screen. The subject-to-screen viewing distances were approximately 50.8 cm. Objects presented on the display screen varied in shape (triangle, rectangle, pentagon), color (red, green, white), size (small, medium, large), heading (N, NE, E, SE, S, SW, W, NW), and screen location (random). Number of symbols per slide varied from 10 to 20. The dimensions of the symbol sizes measured on the surface of the display screen are presented in Table 1. Figure 1 illustrates the display format and allows relative comparisons of the three shapes and three sizes. Each symbol enclosed a solid black triangle, which indicated symbol heading. In 60 slides, all symbols were the same color; in 13 and 47 slides, symbols were of two or three colors, respectively. For all cases, each symbol was one color. Triangles represented airplanes; rectangles and pentagons represented aircraft carriers and destroyers, respectively. All shapes were all sizes and all colors.

Table 1

Symbols and Projected Dimensions (mm)

Symbol		Small	Medium	Large
H▲	H =	8	12	15
	L =	6	8	10
H▣	H =	8	12	15
	L =	6	8	10
H⬠	H =	8	12	15
	L =	6	8	10

During the experiment, questions were presented to the subject on the TV monitor. Questions were written in all capital letters having the following dimensions: height = 7 mm, width = 5 mm, and stroke width approximately 1.5 mm. Table 2 presents the target characteristics used in questions to identify display symbols requiring the subject's response. Questions differed by the amount and the type of information asked. An example of a simple question was: "How many red carriers are on the screen?". This question required subjects to memorize and recall two types of target symbol information: color = red; and shape = carrier; to successfully respond to the subsequently presented display screen. Although the question included the words "... on the screen," no particular screen portion was specified in the question, hence, the subject did not have to remember where (e.g., upper, right, left, etc., part of the screen) to search. An example of a difficult question was: "At least 2 small red destroyers heading south are in the upper screen portion (True or False)?". The difficult question included the following kinds of information to be memorized and recalled: (1) number of question objects = 2; (2) size = small; (3) color = red; (4) shape = destroyer; (5) heading = South; and (6) screen portion = upper.

Procedures. Taped verbal instructions (lasting approximately 5 minutes) with programmed example slides were presented via projector to each subject seated at the test station. Following instructions, the experiment began. The experiment consisted of the presentation of three slide groups, each containing 40 slides. The order of slide presentation within slide group was constant, however, order of slide group presentation was random across subjects. The experimenter started the first trial of each slide group and thereafter the experiment was self-paced. A trial consisted of the following: (1) a question appeared on the TV monitor; (2) subject read the question; (3) subject pressed "Enter" (reaction time 1), which resulted in the simultaneous removal of the question from the TV monitor and presentation of the display slide; (4) subject visually examined the display slide and responded via keypad (reaction time 2) in accordance with the immediately preceding question; (5) display slide was removed from view; and (6) feedback

was presented on the TV monitor. When subject pressed "Enter" again, the next trial began. Reaction times 1 and 2 (RT 1 and 2) were measured in milliseconds. Subjects required 20-25 minutes to complete each slide group.
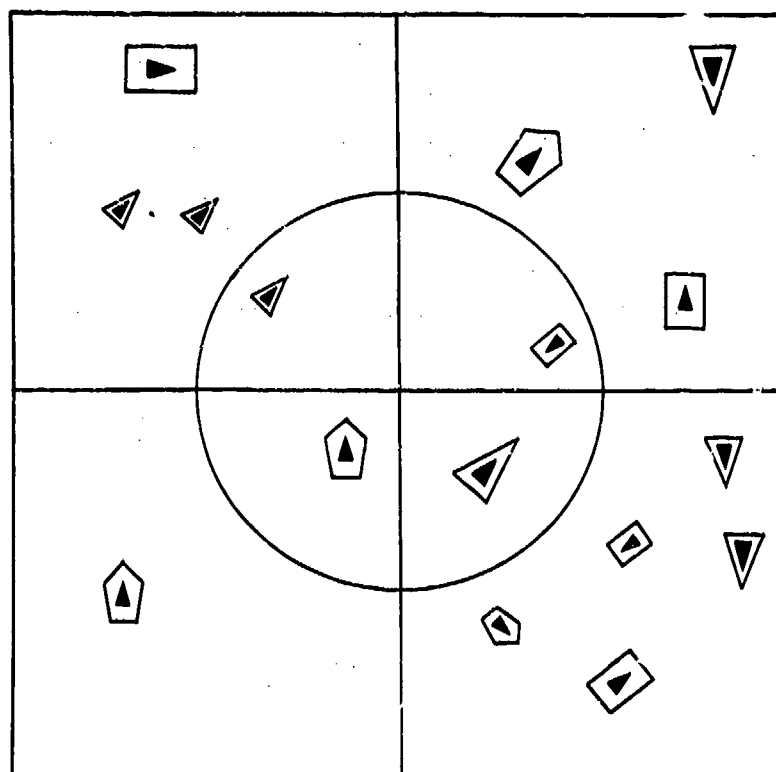

Figure 1. Example display screen slide showing three sizes and three shapes used in experiment.

Table 2*

Target Characteristics that Formed the Questions

Target Characteristic	Definition
Circle Position	Target symbols were either inside or outside the circle.
Screen Portion	Target symbols could be in either the: upper, lower, right, left, upper-left, upper-right, lower-left, lower-right position of the display screen. No specified screen area meant targets could be anywhere in the full screen.
Circle Movement	Target symbols could be moving: To or away from the center of the circle; or would pass through or enter the circle.
Shape	Triangle = airplane; rectangle = carrier; pentagon = destroyer.
Color	Red, green, white.
Size	Small, medium, large.

*Table 2 continued on next page.

Target Characteristics that Formed the Questions

Target Characteristic	Definition
Heading	North, East, South, West, NE, SE, SW, NW.
All red objects represent 2 objects	This required subject to count each red object as really representing 2 objects.
Assume all red objects are rotated 90 degrees to the right	This required subjects to spatially rotate certain display symbols.
Display Screen Objects	Total number of symbols on display screen.
Target Symbols	Number of target symbols to be searched for on display screen.
Number Question Objects	Number of target symbols specified in question.
2 Shapes	Certain questions included 2 shapes, e.g., carriers and airplanes.
2 Headings	Certain questions called for target objects heading in either of 2 specified headings.
2 Sizes	Certain questions called for targets of 2 sizes.
2 Colors	Certain questions called for targets which were either of 2 colors.

Analysis. Table 3 shows how the data were coded for analyses. For each slide, a mean for RT1 (MRT1), a mean for RT2 (MRT2) and a mean percent correct response (MPCR) were computed. The MRT1s and MRT2s for which MPCR accuracy was greater than or equal to 80% provided data input to the statistical analyses. Table 3 illustrates how the question target characteristics were coded for the stepwise regression analyses of MRT2s. Three of the target characteristic variables were continuous--number of screen objects, number of targets, and number of question objects--and were coded accordingly. The remaining variables were dummy coded (7); a "1" indicates that the target characteristic was addressed within the particular question; a "0" indicates the target characteristic was not a part of the question. For example, the question for slide 1 was: "Exactly five objects are in the right portion of the screen (True or False)?". Thus the relevant question target characteristics for RT2 regression analysis were: screen portion (dummy code = 1), and number of question objects = 5. In addition to the question target characteristics for slide 1, there were 10 objects on the display (i.e., NTOT), 6 of which were targets (i.e., NTGT); and are shown appropriately coded in Table 3.

Table 3

Slides Coded for Regression Analyses by Cognitive Processing Demands

SLIDE	SCREEN PORTION	CIRCLE POSITION	CIRCLE MOVEMENT	SHAPE	HEADING	SIZE	COLOR	RED+2	ROTATION	N SCREEN OBJECTS	N TARGETS	N QUESTION OBJECTS	2 SHAPES	2 HEADINGS	2 SIZES	2 COLORS	RT1	RT2	% ACCURACY
1	1	0	0	0	0	0	0	0	0	10	6	5	0	0	0	0	6.806	4.113	96.1
2	1	1	0	0	0	0	0	0	0	12	1	3	0	0	0	0	9.123	3.312	96.1
3	0	0	0	0	0	1	0	0	0	20	7	7	0	0	0	0	7.737	11.873	80.4
:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
28	0	0	0	1	0	0	0	0	0	19	2	3	0	0	0	0	4.681	7.998	96.1
:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
37	0	0	1	1	1	1	1	0	1	18	0	2	0	0	0	0	21.777	10.806	82.4
:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
120	1	1	1	0	0	0	0	0	0	12	3	1	0	0	0	0	12.634	4.074	82.4

Cognitive Processing Demands   Measures

Data analyses were done using the following Statistical Analysis System (8) programs as indicated: PROC STEPWISE, for the stepwise regression analyses of MRT2; PROC CORR, for the simple correlations between MRT1, MRT2, and number of words in the question; and PROC MEANS, for the paired-comparison t tests between MRT1 and MRT2.

RESULTS

Group 1. The results of the stepwise regression analysis for Group 1 MRT2s are presented in Table 4. The abbreviated variables listed below "Intercept" (leftmost column) refer to the following target characteristics:

    CM1   =   circle movement
    ROT   =   rotation
    SP1   =   screen portion
    SZ1   =   1 size
    CLR1 =   1 color
    NQO   =   number of question objects
    SHP2 =   2 shapes
    H2   =   2 headings
    NTOT =   number of display screen objects,

as defined in Table 2. As the R^2 in Table 4 indicates, the nine variables in the regression model accounted for approximately 66% of MRT2 variance. The R^2 = .655; Wherry's shrunken R^2 = .586 (9).

Table 4

Results of Stepwise Regression Analysis for Group 1 MRT2

| Step 9 | Variable SZ1 Entered | | R^2 = 0.6555 | | |
| | | | C(P) = 9.0049 | | |

	DF	Sum of Squares	Mean Square	F	Prob > F
Regression	9	472.4839	52.4982	18.18	0.0001
Error	86	248.3449	2.8877		
Total	95	720.8288			

	B Value	Std. Error	Type II SS	F	Prob > F
Intercept	2.5411				
CM1	1.9093	0.4415	54.0158	18.71	0.0001
ROT	3.7277	0.8624	53.9589	18.69	0.0001
SP1	-1.6976	0.4128	48.8456	16.91	0.0001
SZ1	0.8960	0.5821	6.8424	2.37	0.1274
CLR1	-1.2861	0.5170	17.8717	6.19	0.0148
NQO	0.2290	0.0472	67.9073	23.52	0.0001
SHP2	4.1334	0.9146	58.9707	20.42	0.0001
H2	1.7956	1.0418	8.5790	2.97	0.0884
NTOT	0.1766	0.0574	27.3471	9.47	0.0028

Regression weights (i.e., B value) for each variable's value at first entry into the regression model are provided: SP1 = -2.9373, NQO = 0.1757, CM1 = 2.1052, SHP2 = 3.4309, ROT = 2.3218, NTOT = 0.1603 CLR1 = -1.3017, H2 = 1.9435, and SZ1 = 0.8960. Comparison of the first-entry regression weight values with the final weights in Table 4, and examination of the standard errors for the weights, provide evidence that the regression weight values were quite stable throughout the nine regression steps.

The regression weights provide estimates of time required to process the particular target or display characteristic. For example, to perform the mental rotation (ROT) display component required approximately 3.73 sec. When a subject had to perform a judgment concerning target movement relative to the center of the display (CM1), this added about 1.91 sec to the required display processing time. When the task question limited the required search area (i.e., SP1 was in the question), a reduction in display performance time of about 1.70 sec occurred. Similarly, when a target of a particular color was specified in the question, display RT was reduced by about 1.29 sec. The reductions in MRT2 due to SP1 and CLR1 were evident from their negative regression weights. Display judgments involving one size (SZ1), two shapes (SHP2), a two headings (H2) produced the following RT increments: 0.90, 4.13, and 1.80 sec, respectively. Number of question objects (NQO) and total number of display screen target objects increased MRT2 by 0.23 and 0.18 sec, respectively. Hence, if a display contained 10 symbols to be searched to find the target(s), the increase in search time due to display density was 10(NTOT = 0.1766) = 1.77 sec.

Table 5 shows the order which the variables entered the stepwise regression model for Group 1 MRT2s. The partial R^2 shows the portion of the total MRT2 variance attributed to the variable for that step. The model R^2 value indicates the cumulative MRT2 variance accounted for by variables that have entered through the particular steps. Mallow's criterion (10) for selecting a model, C (P), is presented in the rightmost column.

Table 5

Order Variables Entered Stepwise Regression and Resulting R^2 for Group 1 MRT2

Step	Variable Entered	Number In	Partial R^2	Model R^2	C (P)
1	SP1	1	0.2722	0.2722	87.5777
2	NQO	2	0.0813	0.3534	69.5285
3	CM1	3	0.1178	0.4712	42.4664
4	SHP2	4	0.0582	0.5294	30.1088
5	ROT	5	0.0435	0.5729	21.3685
6	NTOT	6	0.0331	0.6061	15.1946
7	CLR1	7	0.0258	0.6319	10.8167
9	H2	8	0.0141	0.6460	9.3470
9	SZ1	9	0.0095	0.6555	9.0049

Differences between MRT1 and MRT2 were analyzed with a paired-comparison t test; mean MRT1 = 9.6525 sec; mean MRT2 = 6.0881 sec. The mean difference = 3.5644 sec was signifi-cant, $t(1, 95)$ = 7.78, $p < .0001$. Pearson product-moment correlations were computed between the following variables: (1) MRT1 and MRT2, r = .12(df = 1, 94), $p > .10$; (2) MRT1 and number of words in the question, r = .86(df = 1, 94), $p < .001$; and (3) MRT2 and number of words in the question, r = .00.

Group 2. Table 6 presents the results of the stepwise regression analyses for Group 2 MRT2s. Table 6 includes the same abbreviated variables as presented in Table 4 (and defined above), and an additional variable, SHP1 = 1 shape. The regression model accounted for almost 68% of MRT2 variance, quite similar to the R^2 found with Group 1. For the R^2 = .678; the Wherry shrunken R^2 = .613 (9).

Table 6

Results of Stepwise Regression Analysis for Group 2 MRT2

Step 9   Variable CLR1 Entered R^2 = 0.6783
C(P) = 11.2813

	DF	Sum of Squares	Mean Square	F	Prob > F
Regression	9	441.4471	49.0497	19.45	0.0001
Error	83	209.3313	2.5220		
Total	92	650.7784			

	B Value	Std. Error	Type II SS	F	Prob > F
Intercept	1.3127				
CM1	2.2480	0.4383	66.3282	26.30	0.0001
ROT	2.7173	0.8174	27.8695	11.05	0.0013
SP1	-1.3171	0.4346	23.1658	9.19	0.0033
SZ1	1.2627	0.5465	13.4623	5.34	0.0233
SHP1	1.2915	0.5820	12.2905	4.87	0.0300
CLR1	-1.0056	0.5014	10.1445	4.02	0.0482
NQO	0.2527	0.0489	67.4836	26.76	0.0001
SHP2	4.1011	0.8736	55.5783	22.04	0.0001
NTOT	0.2003	0.0526	36.6095	14.52	0.0003

As in Group 1, the regression weights remained stable from first entry values through the nine regression steps. Regression weights upon first entry were as follows: SP1 = -2.8989, NQO = 0.1578, CM1 = 2.0986, SHP2 = 2.9795, NTOT = 0.1937, ROT = 2.1050, SHP1 = 1.5542, SZ1 = 1.3423, and CLR1 = -1.0056. Standard errors of the regression weights in Table 6 are very similar to those in Table 4.

Again, analysis of the regression weights in Table 6 provided indices of the time required to process each display variable as required by the particular questions. Judgments about target movement relative to the display center (CM1) required about 2.25 sec. Mental rotation (ROT), judgments concerning one target size (SZ1) and one shape size (SHP1) were associated with the following increments in display processing times: 2.72, 1.32, and 1.29 sec, respectively. Number of objects specified in the question (NQO), display judgments about two shapes (SHP2), and each of the total display screen objects (NTOT) contributed the following amounts to the total MRT2: 0.25, 4.10, and 0.20 sec, respectively. With, e.g., 15 total symbols on a slide, the effect of display density would be 15(NTOT = 0.2090) = 3.005 sec. As in Group 1, when the question specified a screen portion (SP1), and thereby reduced the screen area to be searched, the display performance time decreased by 1.32 sec. Similarly, specification to search for a target

of a particular color (CLR1) reduced display performance time by about 1 sec. These findings are congruent with those obtained in the stepwise regression analyses for Group 1.

Table 7 presents the order which the variable entered the regression model for Group 2 MRT2s. The partial R^2 and model R^2 values are very similar to those obtained from the Group 1 analysis (see Table 5). The following four variables entered the stepwise regression analyses for Group 1 and 2 at the same step: SP1, NQO, CM1, and SHP2. The variable SHP1 entered the regression analysis for Group 2 but not for Group 1; while R2 entered in Group 1, but not in the Group 2 regression analysis. The remaining variables that entered both Group 1 and 2 final regression models were ROT, NTOT, CLR1, AND SZ1; however, their entry steps differed across regression analyses.

Table 7

Order Variables Entered Stepwise Regression
and Resulting R^2 for Group 2 MRT2

Step	Variable Entered	Number In	Partial R^2	Model R^2	C (P)
1	SP1	1	0.2749	0.2749	100.981
2	NQO	2	0.0717	0.3466	84.198
3	CM1	3	0.1236	0.4702	53.823
4	SHP2	4	0.0479	0.5181	43.260
5	NTOT	5	0.0535	0.5716	31.243
6	ROT	6	0.0391	0.6107	22.992
7	SHP1	7	0.0285	0.6392	17.524
8	SZ1	8	0.0235	0.6627	13.366
9	CLR1	9	0.0156	0.6783	11.281

Again, differences between MRT1 and MRT2 were analyzed with a paired-comparison t test; mean MRT1 = 9.0941 sec; mean MRT2 = 5.8139 sec. The mean difference = 3.2802 sec was significant, $t(1, 95)$ = 7.04, $p < .0001$. Pearson product-moment correlations were computed between the following variables: (1) MRT1 and MRT2, r = .07(df = 1, 93) $p > .10$; (2) MRT1 and number of words in the questions, r = .84(df = 1, 93) $p < .001$; and (3) MRT2 and number of words in the question, r = .01(df = 1, 93).

DISCUSSION

The purpose of this study was twofold: (1) to develop a capability to assess cognitive demands in a complex visual display task requiring certain demands similar to those in real naval aviation tasks, and (2) to develop a capability to predict performance to complex visual displays. In the experimental paradigm employed, information was presented which had to be read, maintained in short-term memory (STM), and used in responding to a visual display. In a similar manner, a TACCO obtains information from various sources (e.g., other displays, crewmembers, computer data banks, and tactical doctrine), which necessarily is held in STM in order to execute a particular task component within the tactical scenario. The present findings of perceptual processing time requirements, given various task demands manipulated herein, provide information relevant to the design of airborne information management systems wherein the operator must quickly interpret complex, multi-dimensional, visual information. Given a display task with similar visual information processing demands, performance predictions are possible. Task demands that have relatively larger regression weights should be avoided whenever other demands having smaller regression weights may be employed. Additionally, human factors engineering efforts should be targeted toward improving performance associated with the larger regression weights; these demands are the ones humans require greater time to perform.

Although the information coding literature is voluminous, and excellent reviews exist (e.g., 11, 12), it is difficult at best to generalize literature results from tasks that, e.g., compared only shape coding versus color coding, to real world displays. An important characteristic of the present study was that the particular display task used included display codes considered relevant (based upon a previous TACCO task analysis (6)) to real world Navy tactical display scenarios. The regression analyses performed on data obtained were congruent with findings in the information coding literature. Tasks requiring search for a target of a particular color enhanced display performance time, as evident by the negative regression weight. Similarly, Christ's (11) review shows that color enhances visual search. The present experimental task and statistical analyses were sensitive to improvement in performance due to reducing the area to be searched. Other research has found that visual search time increases with increased display size (13). Drury and Clement (13) also reported that display density results in increased visual search; a finding congruent with the present results.

Stepwise regression procedures have been criticized for capitalization on chance findings (14), because order of entry of variables is based on purely statistical rather than theoretical criteria. The present study included stepwise regression analyses of data obtained from two groups of subjects, and found quite similar results in both groups. Hence, the obtained results reflect stable regression weight estimates of times required

for processing various demand components included in the present task. Continued research will examine possible theoretical bases for ordering variables in the model. Related to developing such theoretical bases for order of entry, it is interesting that the variable SP1, which delimited area to be searched, entered first in both groups. Much literature exists that supports the notion of global precedence in visual information processing (15, 16). Certainly, the initial perceptual response of segregating the visual field is consistent with the kinds of responses described as global processes and consistent with preattentive visual processes (17).

Another noteworthy finding was the difference between the time required to read alphanumerically presented information into STM, versus the time required to execute this information within the visual display task. The reading time was significantly longer for both groups (3.56 sec for Group 1; 3.28 sec for Group 2). Thus, the decoding of the STM-held information (i.e., analysis of the visual display, comparison of the visual display to the question information, and the display response), occurred faster than the actual encoding of the question. The lack of correlation between MRT1 and MRT2 further illustrates the difference between reading RT and display RT. Unsurprisingly, the MRT1s correlated highly with number of words in the sentence.

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Disclaimer Statement

Opinions or conclusions contained in this report are those of the author and do not necessarily reflect the views or endorsement of the Navy Department.

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DISCUSSION

Bevis, CA

One of the features which distinguishes the real world's - TACCC, for example - task with your experimental paradigm is that the TACCC is in the situation for several hours. He builds up an understanding of what is a slowly evolving situation and, for example, having once determined that two ships in the upper portion of the screen are heading north, he tends to retain that unless his memory is overloaded with other things and refers back to his memory and the screen at some future point in time. Would you care to comment on the implications of this, the long term build up and if you like, keeping track performance, the implications of that for the experimental paradigm that you followed and for your results?

Author's reply

I think the paradigm could be modified to question him on previous situations to see how long he is retaining certain kinds of memory or if there is more degradation in remembering certain aspects of the scenario as he gets farther from the place -- an earlier part in the scenario which would be another critical aspect of his task. This task was designed to measure some of the memory load imposed upon him in a manner that was similar to his actual task although this is certainly an experimental task at best. I think that would be certainly an important additional kind of demand to measure in this task and it would be something, if this program continues, that I think should be studied. I don't have any other answer.

Bevis, CA

Was there any suggestion in your slide sequences that they in some way reflected an evolving situation or were they completely different from slide to slide?

Author's reply

They were completely different. There wasn't a standardized mission in our scenario; possibly that would be a better kind of way to assess this demand in a systematic manner. Thank you - good question.

Stern, US

Was there a relationship between the speed with which they encoded the question and their speed in responding? That did not appear to be a variable in your matrix.

Author's reply

The correlation was about .02.

Stern, US

Different skills?

Author's reply

Right. That supports the difference in reaction time between those two parts of the task.

Billings, U. S.

It didn't appear to me that your predictions derived from these empiric data were very well supported by the empiric data themselves. Was I simply missing something? The predicted and actual value in the two examples you showed us appeared to be off by about 40%.

Author's reply

That's correct. The attained R^2 was about .66 and .68. Those were just examples that were selected because they presented a lot of this kind of information. I didn't select certain ones for this presentation. I don't know why they actually came out that way. Well, one reason would be that these regression weights were just adding up the ones that were in the particular question of the actual R^2. We had all the significant variables accounting for the variance and those regression weights were just applied to that slide and the better prediction would be made to that particular slide had a regression analysis just been based on the number of variables in that slide by doing a separate regression analysis on say color and shape or color, shape and size. The obtained R^2 were shown here for the analysis.